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Weighted mean reproductive indices for matings of individuals of the specified combined ages

Combined ages of mated individuals when mated	*Cases*	*Weighted mean RI*
2 years	796	13.083
3 years	190	11.121
4 years	113	11.119
5 years	12	7.458

The cases are too few to give reliable results after a combined age of four years. Up to that point, however, what occurs is this: There is a significant drop in reproductive ability as we pass from a combined age of two years for the mated birds to three years. In passing from three years to four there is no significant change in reproductive ability. In passing from a combined age of four years to that of five years there is a large drop in the net reproductive ability of the mating.

All of these figures agree in indicating that in the strain of the domestic fowl with which this work was done there is nothing approaching that law of fertility which has been found to hold for mammals, as pointed out at the beginning. Instead we find a steady and progressive decline in fertility after the first breeding season.

[1] Marshall, F. N. A., *The Physiology of Reproduction*, London, 1910, xvii + 706 pp.

[2] Pearl, R., *Science, New York*, N. S., **37**, 1913 (226–228).

[3] King, H. D., *Anat. Rec., Philadelphia*, **11**, 1916 (269–289).

[4] Pearl, R., *J. Exp. Zool., Philadelphia*, **13**, 1912 (155–268).

[5] A complete and detailed report of this work will appear presently in *Genetics*.

A KINETIC HYPOTHESIS TO EXPLAIN THE FUNCTION OF ELECTRONS IN THE CHEMICAL COMBINATION OF ATOMS

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Beginning with Davy[1] and Berzelius, during the first part of the nineteenth century chemists generally accepted the theory that chemical combination is due to electrical forces, but when Dumas discovered the chloroacetic acids in which chlorine atoms, supposedly negative, replace positive hydrogen atoms it was believed that the theory had been shown to be false and it was practically abandoned. Following this, for fifty years or more, a theory of valence which took no account of electrical forces was developed and while occasional reference was made to positive and negative atoms and groups, no definite meaning in an electrical sense was attached to these expressions. Helmholtz in his Faraday lecture in 1881[2] drew the attention of chemists once more to the very close connection between chemical forces and electrical phenomena and spoke for the first time of "atoms of electricity." He also pointed out that the "sulphur of sulphuric acid must be charged with positive equivalents of electricity." In 1887 Arrhenius proposed his theory of electrolytic dissociation and with the help of Ostwald and van't Hoff the belief in a separation of molecules into electrically charged parts in solutions was rapidly accepted. J. J. Thompson[3] gave precision to the atomic character of electricity in 1897 when he demonstrated the material character of cathode rays and the very minute mass of the corpuscles carrying negative charges. Van't Hoff[4] seems to have suggested for the first time that electrically charged atoms may play a part in reactions not usually considered as ionic. The same idea was proposed by the author[5] and by Stieglitz,[6] a little later. J. J. Thompson[7] seems to have been the first to suggest that two atoms may be held together by the electrical foreces resulting from the transfer of an electron from one to the other. He assumed a shell of electrically positive matter within which there was a static arrangement of electrons. Abegg[8] in an entirely independent paper published the same year, discussed the relation between electrons and ionization and the connection with older theories of Helmholtz and others. He also raises, I think for the first time, the question of polar and non-polar volences but seems to have decided that the former are more probable.[9] Rutherford[10] has advanced strong reasons for considering that atoms contain a positive nucleus around which electrons are rotating and this hypotheses has been further developed by Bohr,[11] Nicholson,[12] Moseley[13] and others,

Physicists in general have directed their attention to rotating or rapidly moving electrons and to the relation between these and spectral lines, the disintegration of atoms and other phenomena involving individual atoms. Chemists, on the other hand, following the suggestion of J. J. Thomspson, have considered chiefly the rôle which the valence electrons probably play in the combination of atoms. Sir William Ramsay[14] in his address on "The Electron as an Element" considered that the electron takes a position between the two atoms which are held in combination. In a very recent paper, probably the last which he wrote,[15] he elaborates this thought further and describes models to illustrate the magnetic attractions which would result from electrons rotating in contiguous parts of two molecules. The magneton theory of the structure of the atom has also been developed elaborately by Parson.[16] It cannot account for ionization, where, if we accept the electron theory at all, electrons must be transferred completely from the positive atom or group to the negative.

Falk and Nelson,[17] Fry,[18] L. W. Jones,[19] Stieglitz[20] Bray and Branch,[21] G. N. Lewis,[22] and others have discussed the phenomena connected with the transfer of valence electrons from one atom to another but, with the exception of the magneton theories referred to above, no one, so far as I can discover, has suggested a possible connection between the motion of the valence electrons and chemical combination between atoms.

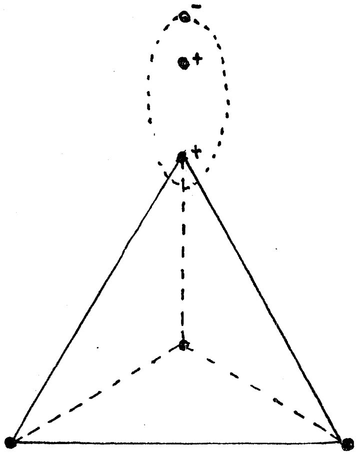
In the hypotheses here proposed the following assumptions, now more or less current among physicists and chemists, are made:

1. The atoms are of a complex structure made up of positive nuclei and electrons, of which the latter, at least, are in very rapid motion. If we assume that the electrons are 1/1800 the mass of hydrogen atoms and that they obey the same laws of motion as other atoms, their average velocity would be about sixty times the velocity of molecules of hydrogen (H_2). I will not attempt to discuss here the question whether the law of equipartition of energy actually holds for electrons.

2. That the electrons are of two kinds in their relation to the structure of the atom. Some of them are so involved in their orbits or motions among the positive nuclei that they can never escape from the atom. Others, called valence electrons, may be transferred to other atoms.

Let us suppose that two atoms, which have an affinity for each other are brought close together. A valence electron which is rotating around a positive nucleus in the first atom may find a positive nucleus in the second atom sufficiently close so that it will include the latter in its orbit and it may then continue to describe an orbit about the positive nuclei of the two atoms. During that portion of the orbit within the second atom that atom would become, on the whole, negative while the first atom would be positive. During the other part of the orbit each atom would be electrically neutral, and the atoms might fall apart. When we remember, however, the tremendous velocity of the electrons and the relatively sluggish motions of the atoms it seems evident that the motion of an electron in such an orbit might hold two atoms together. In ionization the electron would, of course, revolve about the nucleus of the negative atom leaving the other atom positive. It seems impossible to explain ionization otherwise than on the supposition of the complete transfer of the electron. This complete transfer in ionization is one of the strongest arguments against the magneton theory as the only explanation of chemical combination.

An interesting feature of the hypothesis proposed is that it may be used to account for that localization of the affinities in particular parts of atoms which is indicated by many of the properties of organic compounds. Thus if we suppose that there are four (or eight) positive nuclei in a carbon atom around which valence electrons may rotate, an atom of hydrogen may be held to the neighborhood of one of these nuclei as indicated in the figure.



I wish to acknowledge my indebtedness to Julius Stieglitz, R. D. Carmichael, J. B. Shaw, Jacob Kunz, A. P. Carman, A. A. Noyes and R. C. Tolman, who have read the first draft of this paper and of whom several have made helpful suggestions.

[1] Davy, *London, Phil. Trans. R. Soc.*, 1807, p. 1.

[2] Helmholtz, *London, J. Chem. Soc.*, **24**, 1881, (291).

[3] Thomson, J. J., *Phil. Mag., London*, (Ser. 5), **44**, 1897, (291).

[4] Van't Hoff, *Ibid.*, **23**, 1901, (797).

[5] Noyes, W. A., *J. Amer. Chem. Soc., Easton, Pa.*, **23**, 1901, (463).

[6] Stieglitz, *Ibid.*, **23**, 1901, (797).

[7] Thomson, J. J., *Phil. Mag., London*, (Ser. 6), **7**, 1904, (237).

[8] Abegg, *Zs. Anorg. Chem., Hamburg*, **39**, 1904, (330).

[9] *Loc. cit.*, Note 8, p. 347.

[10] Rutherford, E., *Phil. Mag., London*, (Ser. 6), **21**, 1911, (669).

[11] Bohr, N., *Ibid.*, **26**, 1913, (1, 476, 857). On p. 862 Bohr discusses the hypothesis that atoms may be held in combination by electrons rotating about the line joining the positive nuclei of two atoms. This is similar to Ramsay's view mentioned below.

[12] Nicholson, *Phil. Mag., London*, (Ser. 6), **27**, 1914, (54).

[13] Moseley, *Ibid.*, **26**, 1913, (1024).

[14] Ramsay, Sir W., *London, J. Chem. Soc.*, **93**, 1908, (774).

[15] Ramsay, Sir W., *London, Proc. R. Soc.*, (A), **92**, 1916, (451.)

[16] Parson, A magneton theory of the structure of the atom, *Washington, Smithsonian Inst., Misc. Collect.*, **65**, 1915, No. 11.

[17] Falk and Nelson, *New York, Sch. Mines Q., Columbia Univ.*, **30**, 1909, (179)., *J. Amer. Soc., Easton, Pa.*, **32**, 1910, (1637).

[18] Fry, *J. Amer. Chem., Soc., Easton, Pa.*, **34,** 1912, (1268), *Zs. physik. Chem., Leipzig,* **76,** 1911, (385, 398, 591).

[19] Jones, L. W., *J. Amer. Chem., Easton, Pa.*, **36,** 1914, (1268).

[20] Stieglitz, *Ibid.*, **36,** 1914, (272); **38,** 1916, (2046).

[21] Bray and Branch, *Ibid.*, **35,** 1915, 1913, (1440).

[22] Lewis, G. N., *Ibid.*, **35,** 1915, (1448).

TRANSVERSE DISPLACEMENT INTERFEROMETRY

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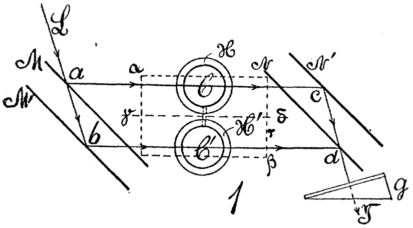
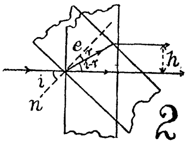
1. Vertical Displacement of Ellipses.—In the diagram figure 1, M and N are half silvered, M' and N' opaque mirrors; C and C' the U tube referred to in the preceding note and here to be removed. L is the collimated beam of white light and $G\ T$ the direct vision spectroscope.

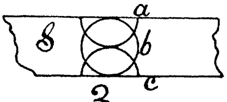
If the fringes are too small, when horizontally centered by the micrometer, the center of ellipses may be brought into the middle of the field of the telescope by sliding one component beam vertically over the other without appreciably changing the direction of the rays. In other words one illuminated spot at d, figure 1, is to move vertically relative to the other by a small amount. This may be done by placing a thick plate glass compensator such as is seen in figure 2 in each of the component beams *abd* and *acd* and suitably rotating one plate relative to the other, each on a horizontal axis. Very little rotation is required. In the same way elliptical fringes may be changed to nearly linear horizontal fringes when desirable. If the fringes are to be sharp the slit must be very fine. When sunlight is used with a slit not too fine, each of the coincident sodium lines (D_1D_2) frequently shows a sharply defined helical or ropelike structure. This is a special phenomenon, which will be given further consideration presently.



1



2



3

The first result is interesting inasmuch as it is thus possible to displace the centers of ellipses not only horizontally as usual relative to the fixed sodium lines in the spectrum, but also *vertically* relatively to